# DORMITZER & LABELLE

# Investigation and Proposed Change

## of the Lighting Facilities of

## the Urbana Presbyterian Church

## Electrical Engineering

## B.S.

## 1911

# INVESTIGATION AND PROPOSED CHANGE

OF THE

# LIGHTING FACILITIES OF THE URBANA PRESBYTERIAN CHURCH

BY

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JOHNSTON NOBLE LABELLE

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THESIS

FOR THE

## DEGREE OF BACHELOR OF SCIENCE

IN

## ELECTRICAL ENGINEERING

.

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COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
1911

# UNIVERSITY OF ILLINOIS

May 29                    1911

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Max Robert Dormitzer and Johnston Noble LaBelle.

ENTITLED    Investigation and Proposed Change of the Lighting

Facilities of the Urbana Presbyterian Church.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF   Bachelor of Science in Electrical Engineering.

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HEAD OF DEPARTMENT OF Electrical Engineering.

197590

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# INVESTIGATION AND PROPOSED CHANGE OF
## THE LIGHTING FACILITIES OF THE URBANA PRESBYTERIAN CHURCH.

The art of illumination may be defined as the art of using ar-
tificial sources of light.  In this work the ultimate question is
the amount of useful light furnished the eye for the required pur-
poses and fulfilling the necessary requirements with respect to
color and steadiness.  The intensity of light at a given point is
determined by the amount of luminous radiation and the distance of
the point from that source.  Thus the intensity at any point varies
with the square of the distance to that point, provided the distance
is large compared with the dimensions of the source.

The distribution of light from luminous sources is generally
modified by the use of shades or reflectors, so that the actual in-
tensity in any given direction must be determined before applying
the law of inverse squares.  For ordinary purposes of calculating
direct illumination the law of inverse squares holds.

Besides this law, the illuminating engineer must always keep
in mind that illumination must be acceptable to the eye.  Objects
should be seen clearly and with a minimum of fatigue.  The require-
ments for good illumination involve the following considerations:
(1) There must be sufficient illumination.  Since objects are seen
by means of the light they reflect, more light must be thrown on
dark objects than on light ones.  (2)  There must not be too much il-
lumination, for too strong light tires the eyes. (3)  Intensely bright
lights in the field of vision should be avoided, for they produce an
exceedingly disagreeable glare.  The iris closes somewhat in order to
afford a protection from such lights and the amount of light received

from illuminated objects is thereby so reduced that they cannot be seen clearly. (4) Flickering lights should be avoided. (5) Lamps should be so placed that the light is not regularly reflected into the eye. (6) Streaks or striations in the illumination are undesirable. (7) Satisfactory light should be of a proper quality. It should have a continuous spectrum, that is, one containing every color, in order that the relative color value of objects illuminated may be the same as when seen by daylight.
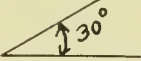
The proper intensity of church illumination is usually considered as being from 1.5 to 2 foot candles. This intensity should be as nearly uniform as possible over the entire area.

In view of remedying the illumination, the Presbyterian Church situated on Green Street in Urbana was investigated. It was found that the lighting of the church was accomplished by means of a large chandelier located in the center, and several wall brackets. The lamps were of the carbon type, 16 candle power. The distribution was very poor, being very intense for a few feet around the chandelier and decreasing to very near nothing around the back seats and walls. The chandelier was also hung too low, throwing an unpleasant glare into the eyes of the people sitting in the pews just behind and to the side. As a whole, it could readily be seen that there was much room for improvement.

It was first necessary to ascertain the intensity of the present illumination. This was done by means of a photometer. The one used was a Sharp-Millar portable photometer. It was first calibrated by means of a test lamp No. 2844. This is a 32 candle-power lamp. The accompanying tables show the readings taken, resulting in an average electromotive force value of 96.07 volts.

Photometric measurements were first made over the entire room and the exact state of illumination determined for a horizontal plane and a plane 30° with the horizontal as shown. It was found that the intensity of illumination for the horizontal plane varied from a maximum of 1.87 foot candles to a minimum of .18 foot candles at the rear of the room. For the 30° plane the maximum illumination was 1.48 foot candles and the minimum was .05 foot candles. The power used by these lights was found to be 4000 watts. The dimensions of the whole auditorium including the choir loft are 52 1/2 feet wide by 49 feet long. The choir loft area was omitted from the consideration leaving an area for the auditorium equal to 2125 square feet.

With the above data it was possible to calculate a more uniform distribution.

It was decided to consider the installation of four small chandeliers, located as shown in diagram 3, each chandelier to consist of 5  60-watt tungsten lamps making a unit of 300 watts. The required lumens for the given area would be

$$1.5 \times 2125 = 3190 \text{ lumens.}$$

The effective lumens per lamp for 9  60-watt tungstens = 250.

Lumens given by all of the lamps = 250 x 5 x 4 = 5000.

$$5000 - 3190 = 1810 \text{ lumens - excess.}$$

The above consideration was for a clear lamp, but when a reflector and frosted globe are added, the effective lumens are reduced to about the proper number.

In the calculation of the intensity of illumination it can usually be figured that there will be some increase of illumination due to the reflection from the ceiling and walls, but in the propo-

sition under consideration the amount that is reflected by the ceiling and walls is practically negligible. The ceiling and walls are very dark, the ceiling being of dark brown wood and the walls of a dark orange tint. Thus it may be seen that the amount of reflected light will be very small.

The above point was one of the determining factors in the selection of a proper reflector, so a reflector which allowed only a small portion of the light to go towards the ceiling was selected. The Holophane Class B Stalactite reflector gave a good distribution curve for this proposition, so it was chosen. Figure 4 shows the distribution for such a reflector with a 60 watt, 50 candle power Mazda lamp.

The next consideration is the proper height and location of the fixtures.

The shape of the ceiling governs the location of the fixtures in this case. Because of the cut-up condition of the ceiling, they must be hung along the center lines of the church. The height of the fixtures should be such as to bring the proper illumination upon the plane considered. It is important, however, that they shall be located so as to be accessible for cleaning and renewals. The height decided upon was 13 feet above the plane, or about 16 feet from the floor. This would make the length of the chandelier 14 feet.

In order to find the intensity of illumination at any point, the National Electric Lamp Association's Bulletin was used. This bulletin gives the intensity of illumination in foot candles on the horizontal plane at points various distances from a light source of 1 candle power, the horizontal distance being measured from a

point directly under the light source to the point where the intensity is desired.  Thus to find the intensity of a point directly under one of the chandeliers, neglecting the light from the others, is a very simple operation.  Referring to the table it is found that a light source of 1 candle power gives an intensity of illumination of .00592 foot candles upon a plane 13 feet below.  From the distribution curve the  intensity  per lamp is found to be 38 candle power.  Hence for the five lamps composing the unit the total would be 190 candle power.  Therefore the intensity would be .00592 x 190= 1.13 foot candles.  In a similar manner the intensity due to the other fixtures may be found, and the sum will give the total intensity in foot candles at the point considered.

Having determined a means of finding the foot candles at any point on the plane for the given condition of lighting, the next step is to calculate the illumination along some definite lines and compare the results with the illumination along the same lines as it exists now.  The intensity for different positions as obtained by the photometer readings for the horizontal and 30° plane were recorded on a plat of the church auditorium drawn to a certain scale. Equal intensity lines were then drawn over these plats.  The lines OC, OD, OE, were chosen (see figures 1 and 2) and the intensity at each pew recorded.  The values of illumination found were plotted as ordinates with the pew numbers as abscissas.  The resulting curves show the condition of illumination from the front to the rear of the church.  Figures 5 and 6 show these curves.

The illumination for the proposed system was next considered. The intensity for the same points were calculated, the accompanying table showing the results.  A curve was then drawn showing the re-

sulting illumination. The contrast with the first curves can easily
be seen by a comparison of the two. The new system results in a
maximum intensity of 2.2 foot candles and a minimum of 1.46 foot
candles along the center line. This gives an average of 1.83 foot
candles. The maximum of the present system for the same line is
only 1.87 foot candles.

A few other points were calculated. The location of these
points is shown in Figure 3, the points being E, F, G, etc. The re-
sulting intensity is shown in tabular form by the accompanying table.
This shows that at the point O in the most remote corner the inten-
sity is .66 foot candles. Side brackets at this point would raise
the intensity to the required 1 1/2 foot candles.

It is considered that the lights in churches burn on the aver-
age 600 hours a year. The wattmeter test shows that the present
lighting system requires 4000 watts. This would make a total of
4000 x 600 = 2,400,000 watt hours, or 2400 kilowatt hours. Power
costs 15 cents a kilowatt hour. Hence .15 x 2400 = $360.00 present
cost of lighting.

By the new system the total watts required would be 4 x 300 =
1200 watts.

1200 x 600 = 720000 watt hours, or 720 kilowatt hours.

.15 x 720 = $108.00

$360 - $108 = $252.00 saved per year by the new system.

The cost of renewals may be considered as follows:

The life of the carbon lamp is approximately 600 hours, or one
church year. The life of the Tungsten lamp is 1000 hours. On this
basis the carbon lamps would need to be renewed every year while the
Tungsten lamp will burn 1 2/3 years.

There are 60 carbon lamps in the church. These lamps cost 20 cents each. Hence cost of renewals per year is 60 x 20¢ = $12.00.

The cost of the Tungsten lamp is $1.00. Since there are 20 of these used according to the proposed system, the cost of renewals per year would be 20 x .6 x $1.00 = $12.00. Thus it can be seen that there is no difference in cost of renewals between the two systems, and hence the saving is all due to the smaller amount of power used.

In conclusion it may be said that the proposed system fulfills the condition for correct illumination and reduces the cost of lighting to less than one third of the original cost.

CALIBRATION OF THE PHOTOMETER TEST LAMP NO. 2844
32 C.P.
WESTON A. C. VOLTMETER NO. 2918.

| Distance from test lamp | Intensity Ft.Candles | Voltmeter reading | Corrected reading |
|---|---|---|---|
| 2 | 8 | 98.5 | 97.5 |
| 3 | 3.55 | 97 | 96 |
| 4 | 2.00 | 96 | 95 |
| 5 | 1.28 | 97 | 96 |
| 5.66 | 1.00 | 97 | 96 |
| 6 | .88 | 97 | 96 |
| 7 | .65 | 97 | 96 |

Average, 96.07

## READINGS TAKEN BY PHOTOMETER
### Horizontal Plane
### (Present conditions)

### SECTION I.
#### Intensity Ft.- Candles.

| No. of Pew | Left Side | Center | Right Side |
|---|---|---|---|
| 1 | .23 | | .40 |
| 2 | .19 | | .38 |
| 3 | .18 | | .45 |
| 4 | .15 | | .41 |
| 5 | .30 | | .36 |
| 6 | .48 | | .33 |
| 7 | .33 | | .38 |
| 8 | .32 | | .30 |
| 9 | .65 | | .32 |
| 10 | .65 | | .35 |

### SECTION II.
#### Intensity Ft.-Candles.

| No. of Pew | Left Side | Left of Center | Center | Right of Center | Right Side |
|---|---|---|---|---|---|
| 1 | .74 | ---- | 1.23 | ---- | .78 |
| 2 | .82 | 1.35 | ---- | 1.45 | .94 |
| 3 | .82 | 1.52 | 1.87 | 1.36 | .89 |
| 4 | .70 | 1.50 | 1.62 | 1.11 | .80 |

### SECTION III.
#### Intensity Ft.-Candles.

| No. of Pew | Left Side | Center | Right Side |
|---|---|---|---|
| 1 | .50 | .95 | 1.1 |
| 2 | .38 | .71 | .82 |
| 3 | .31 | .42 | .53 |
| 4 | .29 | .36 | .41 |
| 5 | .34 | .26 | .27 |
| 6 | .19 | .20 | .20 |

### SECTION IV.
#### Intensity Ft.-Candles.

| No. of Pew | Left Side | Center | Right Side |
|---|---|---|---|
| 1 | 1.3 | .95 | .63 |
| 2 | .90 | .70 | .45 |
| 3 | .56 | .43 | .31 |
| 4 | .40 | .35 | .35 |
| 5 | .30 | .36 | .37 |
| 6 | .19 | .20 | .28 |

## SECTION V.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Right Side |
|---|---|---|
| 1 | .46 | .23 |
| 2 | .47 | .27 |
| 3 | .53 | .23 |
| 4 | .53 | .21 |
| 5 | .48 | .37 |
| 6 | .43 | .44 |
| 7 | .39 | .34 |
| 8 | .39 | .34 |
| 9 | .35 | .52 |
| 10 | .40 | .9 |

## PULPIT PLATFORM.
### Intensity Ft.-Candles.

Front of platform ........... .35
Center of platform........... .42
Left side of platform ....... .56
Right side of platform ...... .50

## CHOIR LOFT.
### Intensity Ft.-Candles.

Left Side ............ .35
Left of Center ....... .86
Center ............... .90
Right of Center ..... 1.00
Right Side ........... .34

## REAR OF CHURCH AUDITORIUM.
### Intensity Ft.-Candles.

Left Side ............ .14
Left of Center ....... .14
Center ............... .16
Right of Center ...... .14
Right Side ........... .14

READINGS TAKEN BY PHOTOMETER
30 Degrees from Horizontal
(Present conditions)

## SECTION I.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Right Side |
|---|---|---|
| 1 | .3 | .39 |
| 2 | .27 | .28 |
| 3 | .15 | .27 |
| 4 | .17 | .26 |
| 5 | .46 | .21 |
| 6 | .57 | .19 |
| 7 | .18 | .22 |
| 8 | .32 | .24 |
| 9 | .67 | .16 |
| 10 | .39 | .28 |

## SECTION II.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Left of Center | Center | Right of Center | Right Side |
|---|---|---|---|---|---|
| 1 | .75 | ---- | 1.31 | ---- | .98 |
| 2 | .73 | 1.32 | ---- | 1.46 | .92 |
| 3 | .61 | 1.05 | 1.57 | 1.13 | .60 |
| 4 | .39 | .81 | .99 | .80 | .48 |

## SECTION III.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Center | Right Side |
|---|---|---|---|
| 1 | .18 | .45 | .68 |
| 2 | .11 | .26 | .38 |
| 3 | .14 | .11 | .12 |
| 4 | .21 | .095 | .09 |
| 5 | .36 | .08 | .075 |
| 6 | .07 | .07 | .07 |

## SECTION IV.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Center | Right Side |
|---|---|---|---|
| 1 | .48 | .40 | .28 |
| 2 | .15 | .15 | .13 |
| 3 | .09 | .15 | .17 |
| 4 | .085 | .10 | .24 |
| 5 | .08 | .10 | .41 |
| 6 | .075 | .07 | .15 |

## SECTION V.
### Intensity Ft.-Candles.

| No. of Pew | Left Side | Right Side |
|---|---|---|
| 1 | .42 | .195 |
| 2 | .45 | .21 |
| 3 | .45 | .17 |
| 4 | .40 | .20 |
| 5 | .26 | .40 |
| 6 | .20 | .35 |
| 7 | .19 | .145 |
| 8 | .25 | .30 |
| 9 | .33 | .65 |
| 10 | .40 | .70 |

## PULPIT PLATFORM.
### Intensity Ft.-Candles.

Front ....... .35
Center ...... .22
Left Side ... .60
Right Side .. .48

## CHOIR LOFT.
### Intensity Ft.-Candles.

Left Side ............ .40
Left of Center ....... .75
Center ............... .80
Right of Center ...... .75
Right Side ........... .38

## REAR OF CHURCH AUDITORIUM.
### Intensity Ft.-Candles.

Left Side ............ .06
Left of Center ....... .04
Center ............... .02
Right of Center ...... .055
Right Side ........... .055

This table shows the calculated intensity of illumination
for the various points along line D, on the horizontal plane.

(For proposed change)

| | PEW | Chande-lier I | Chande-lier II | Chande-lier III | Chande-lier IV | Total intensity along D in Ft.Candles |
|---|---|---|---|---|---|---|
| 1 | Distance<br>Intensity | 18<br>.309 | 21.5<br>.229 | 18<br>.309 | 3.5<br>1.06 | 1.907 |
| 2 | Distance<br>Intensity | 15<br>.432 | 15<br>.432 | 15<br>.432 | 6.5<br>.924 | 2.220 |
| 3 | Distance<br>Intensity | 14.5<br>.433 | 12<br>.587 | 14.5<br>.433 | 9.5<br>.73 | 2.183 |
| 4 | Distance<br>Intensity | 14.5<br>.433 | 9.<br>.731 | 14.5<br>.433 | 12.5<br>.542 | 2.139 |
| 5 | Distance<br>Intensity | 15<br>.432 | 6<br>.962 | 15<br>.432 | 15.5<br>.402 | 2.228 |
| 6 | Distance<br>Intensity | 16.5<br>.375 | 3<br>1.094 | 16.5<br>.375 | 19<br>.273 | 2.117 |
| 7 | Distance<br>Intensity | 18<br>.309 | 0<br>1.13 | 18<br>.309 | 21.5<br>.229 | 1.977 |
| 8 | Distance<br>Intensity | 19<br>.273 | 3<br>1.094 | 19<br>.273 | 24.5<br>.22 | 1.86 |
| 9 | Distance<br>Intensity | 22<br>.224 | 6<br>.962 | 22<br>.224 | 27.5<br>.20 | 1.61 |
| 10 | Distance<br>Intensity | 24.5<br>.26 | 9<br>.731 | 24.5<br>.22 | 30.5<br>.18 | 1.571 |
| Back Wall | Distance<br>Intensity | 28.5<br>.19 | 13.5<br>.39 | 28.5<br>.19 | 35<br>.14 | .91 |
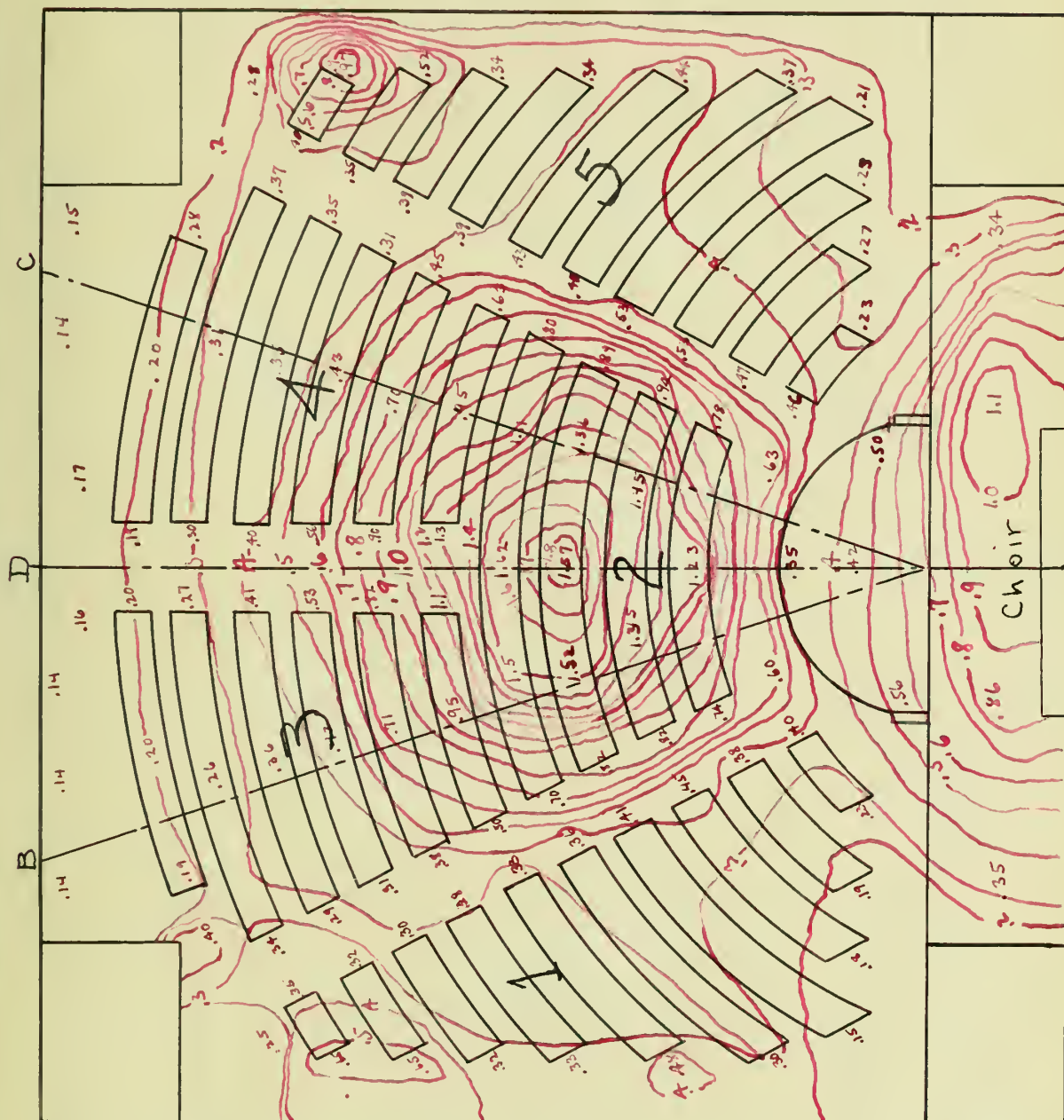
Fig. 1
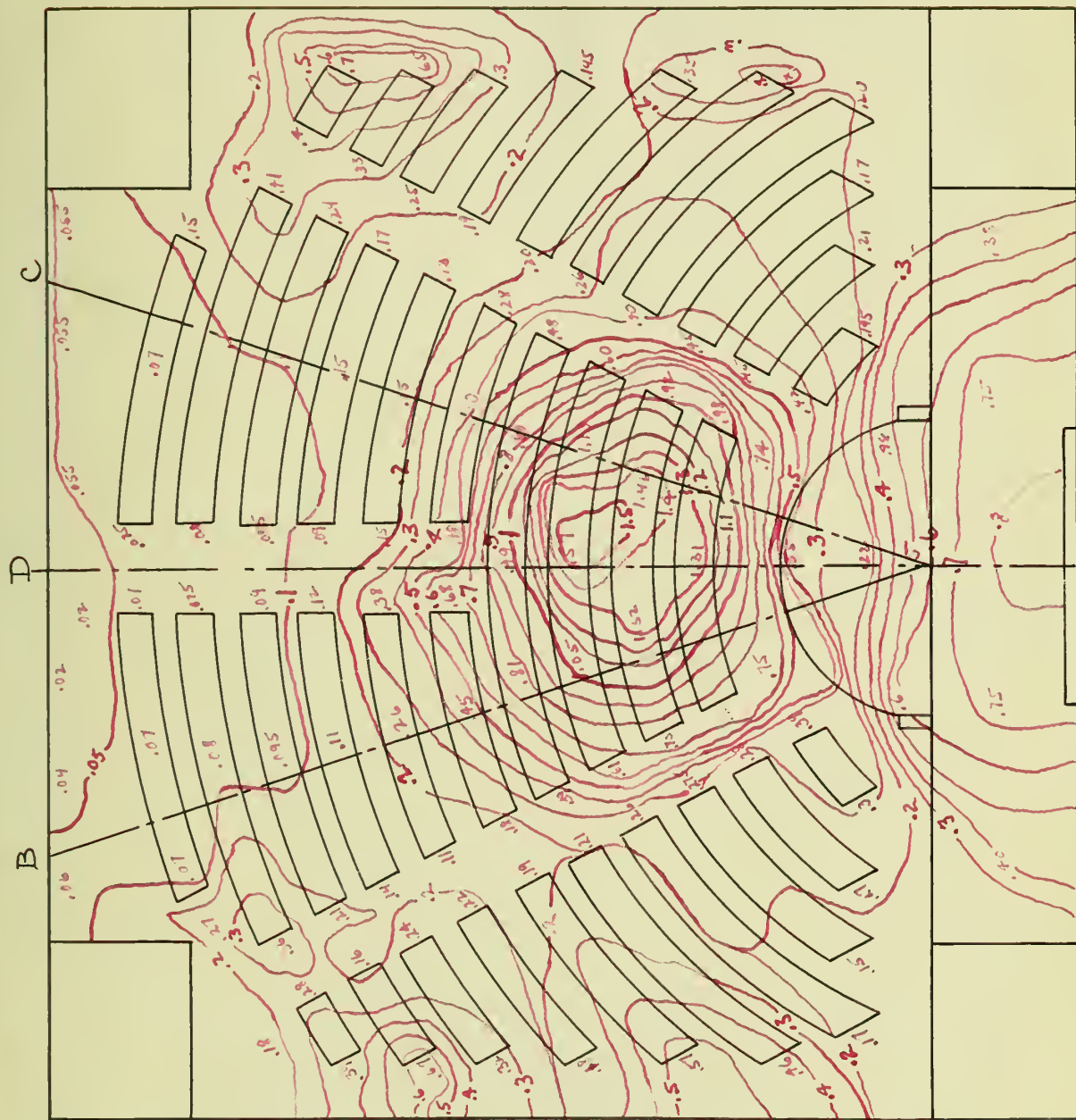
Fig. 2.    Plane 30° to Horizontal.
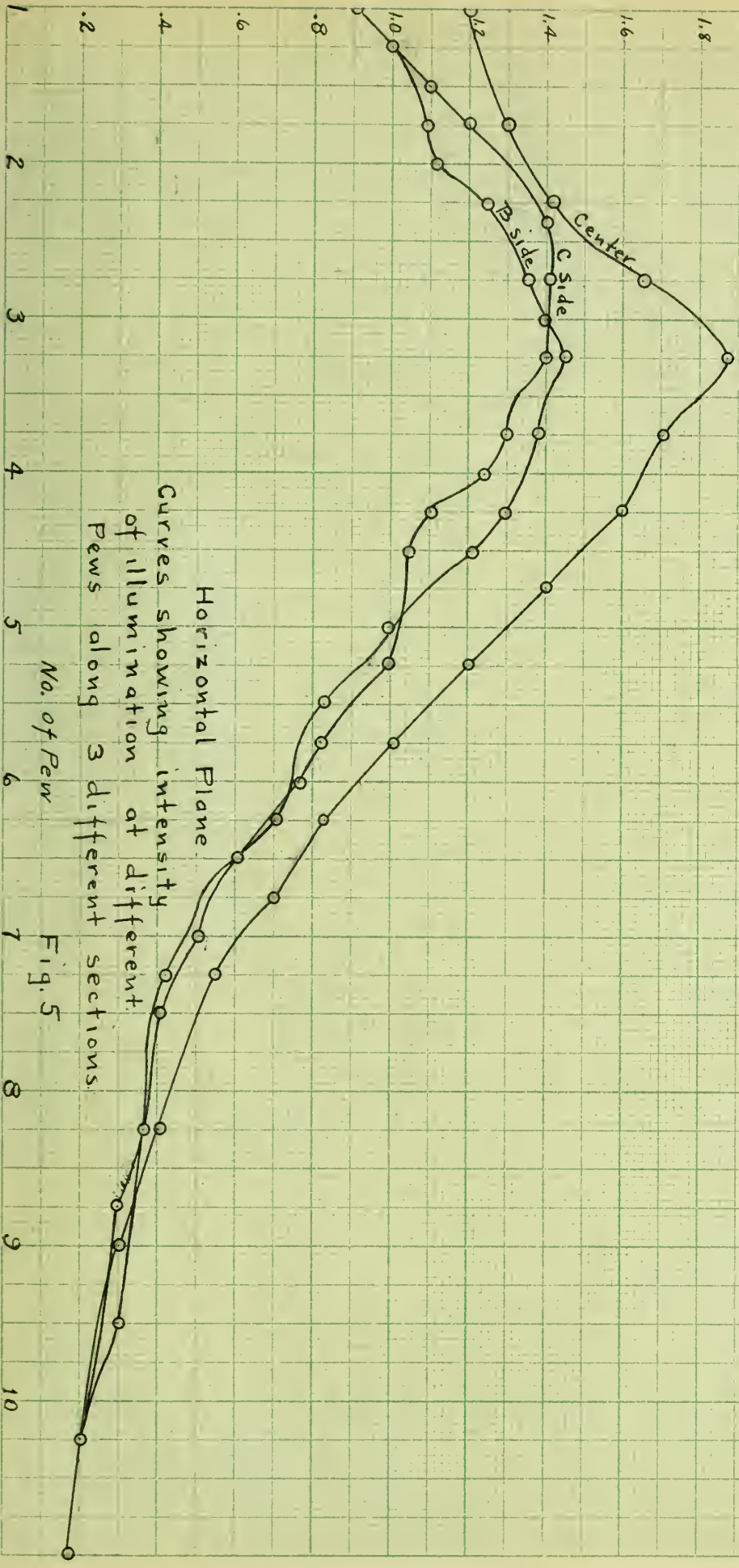
Fig. 5

Horizontal Plane
Curves showing intensity
of illumination at different
Pews along 3 different sections.

Intensity of Illumination in
Foot-Candles

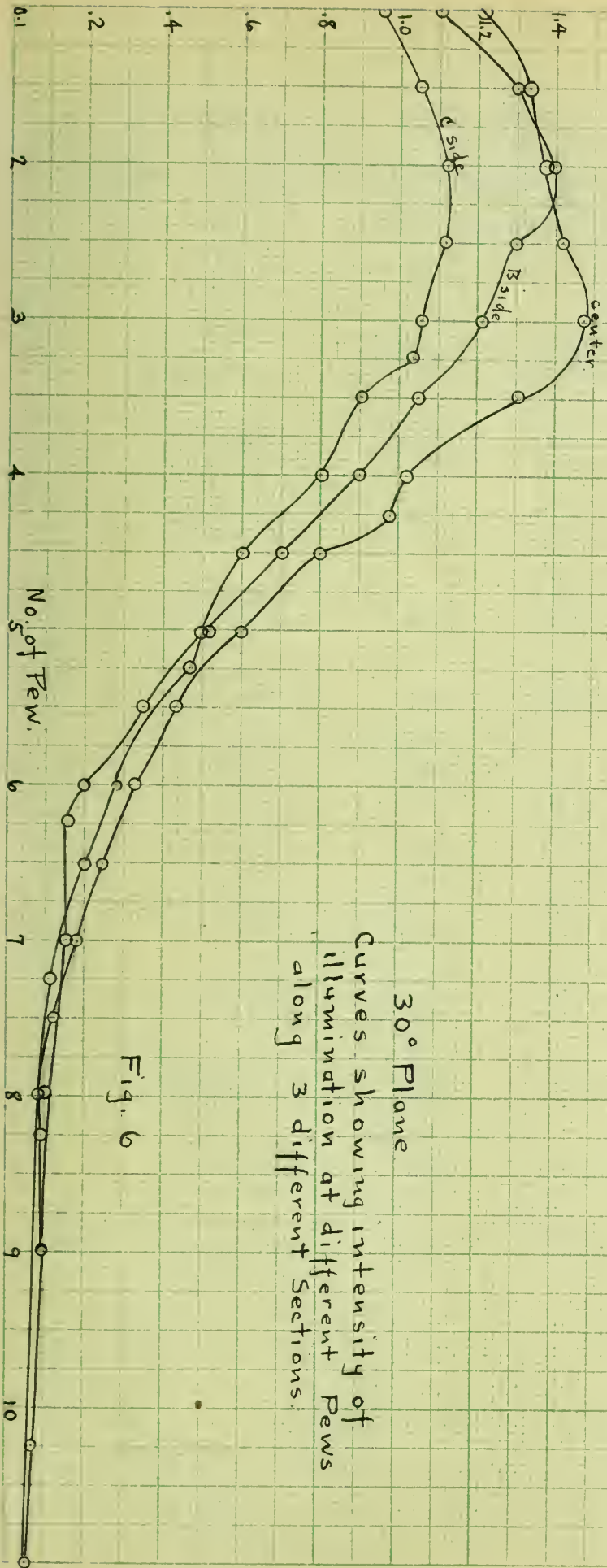No. of Pew

Intensity of Illumination
Foot-candles.

No. of Pew.

Fig. 6

30° Plane
Curves showing intensity of
illumination at different Pews
along 3 different Sections.

c side

B side

center

This table shows the calculated intensity of illumination
for the various points along line B or C, on the horizontal plane.
(For proposed change)

|  | PEW | Chandelier I. | Chandelier II | Chandelier III | Chandelier IV | Total intensity along B & C Ft.Candles |
|---|---|---|---|---|---|---|
| 1 | Distance<br>Intensity | 13.5<br>.39 | 18.5<br>.283 | 19.0<br>.273 | 4.5<br>1.00 | 1.946 |
| 2 | Distance<br>Intensity | 11.0<br>.645 | 16<br>.385 | 19.0<br>.273 | 7.5<br>.778 | 2.081 |
| 3 | Distance<br>Intensity | 8<br>.823 | 13.5<br>.390 | 19.5<br>.258 | 10.5<br>.655 | 2.126 |
| 4 | Distance<br>Intensity | 8<br>.823 | 11.5<br>.600 | 20.5<br>.236 | 13.5<br>.39 | 2.049 |
| 5 | Distance<br>Intensity | 8<br>.823 | 10<br>.71 | 21.5<br>.229 | 16.5<br>.375 | 2.137 |
| 6 | Distance<br>Intensity | 9<br>.731 | 9.5<br>.73 | 23.5<br>.227 | 19.5<br>.258 | 1.946 |
| 7 | Distance<br>Intensity | 11<br>.645 | 9.5<br>.73 | 25<br>.218 | 22.5<br>.22 | 1.813 |
| 8 | Distance<br>Intensity | 13<br>.525 | 10.5<br>.65 | 26.5<br>.214 | 25.5<br>.216 | 1.605 |
| 9 | Distance<br>Intensity | 15.5<br>.402 | 12<br>.587 | 29.5<br>.205 | 28.5<br>.19 | 1.384 |
| 10 | Distance<br>Intensity | 18.5<br>.283 | 14<br>.481 | 32<br>.168 | 31.5<br>.17 | 1.102 |
| Back Wall | Distance<br>Intensity | 24.5<br>.22 | 19.5<br>.258 | 37<br>.1305 | 37.5<br>.13 | .7385 |

This table shows the calculated intensity of illumination in foot candles for points E,F,G,H,J, and O, on the horizontal plane, as shown on diagram of proposed change.

| | POSITION | Chande-lier I | Chande-lier II | Chande-lier III | Chande-lier IV | Total intensity in Ft.Candles |
|---|---|---|---|---|---|---|
| E | Distance | 0 | 18.5 | 28 | 18.5 | 1.89 |
| | Intensity | 1.13 | .283 | .195 | .283 | |
| F | Distance | 4 | 18 | 30.5 | 21.5 | 1.758 |
| | Intensity | 1.04 | .309 | .180 | .229 | |
| G | Distance | 8 | 19 | 33.5 | 25.5 | 1.572 |
| | Intensity | .823 | .273 | .160 | .216 | |
| H | Distance | 12 | 21 | 36 | 29.5 | 1.157 |
| | Intensity | .587 | .230 | .135 | .205 | |
| J | Distance | 16 | 23 | 39.5 | 33.5 | .88 |
| | Intensity | .400 | .215 | .115 | .15 | |
| O | Distance | 20. | 26 | 43 | 37.5 | .66 |
| | Intensity | .236 | .214 | .08 | .13 | |
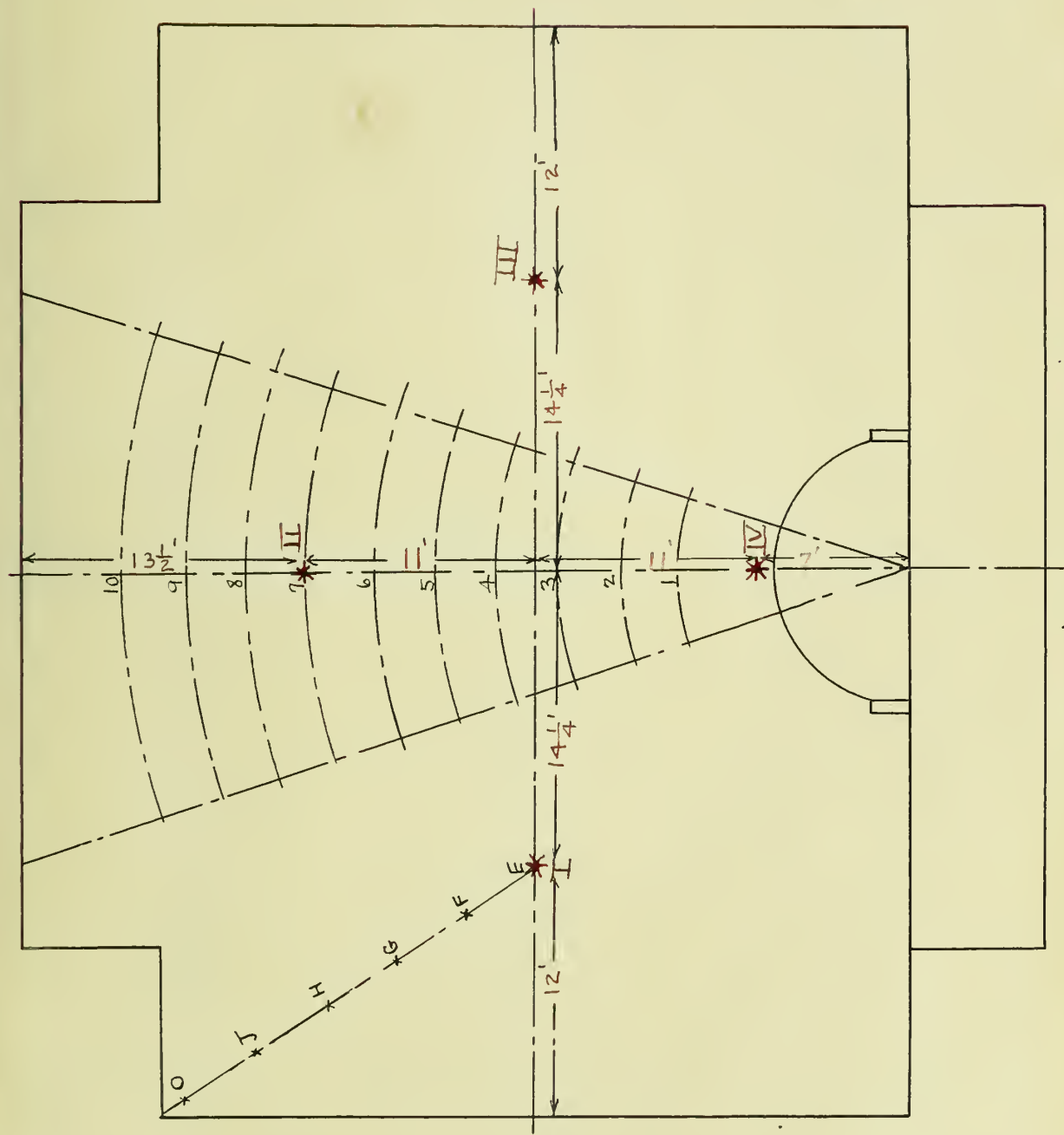
Location of Chandeliers
—·— Centers of Pews.

Fig. 3

Intensity of Illumination in
Foot-Candles.

Center

B or C. Side

No. of Pew.
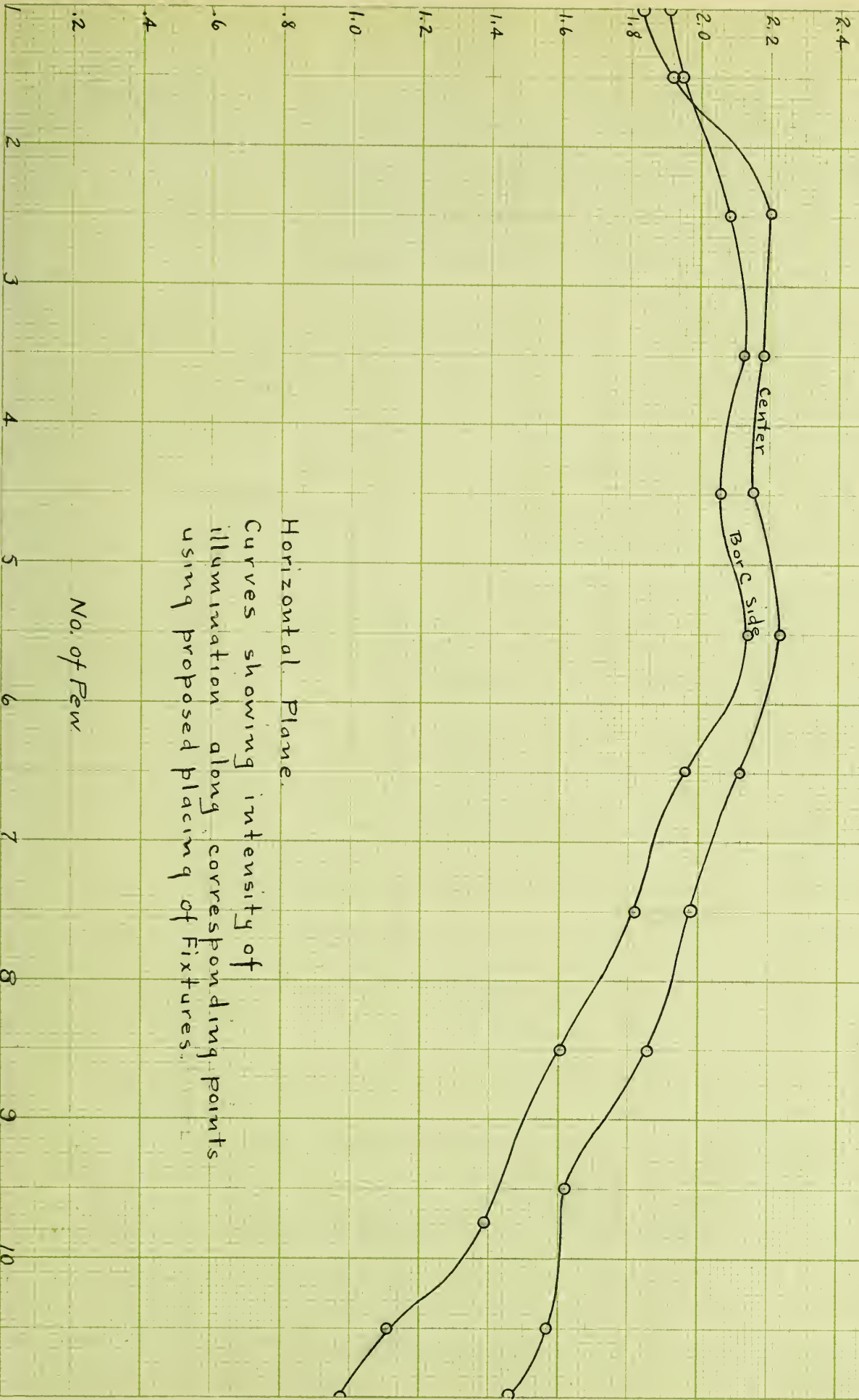
Horizontal Plane.
Curves showing intensity of
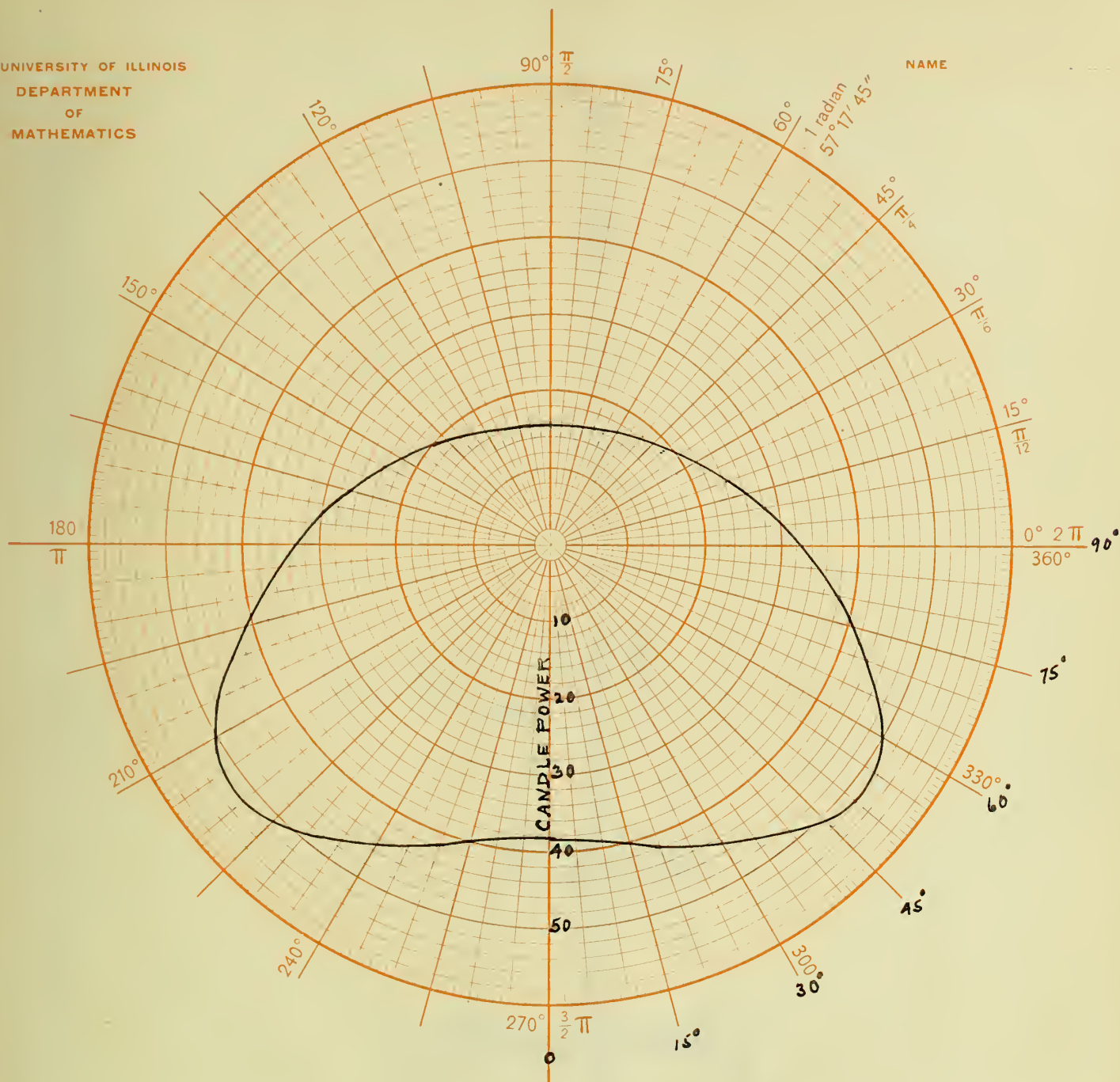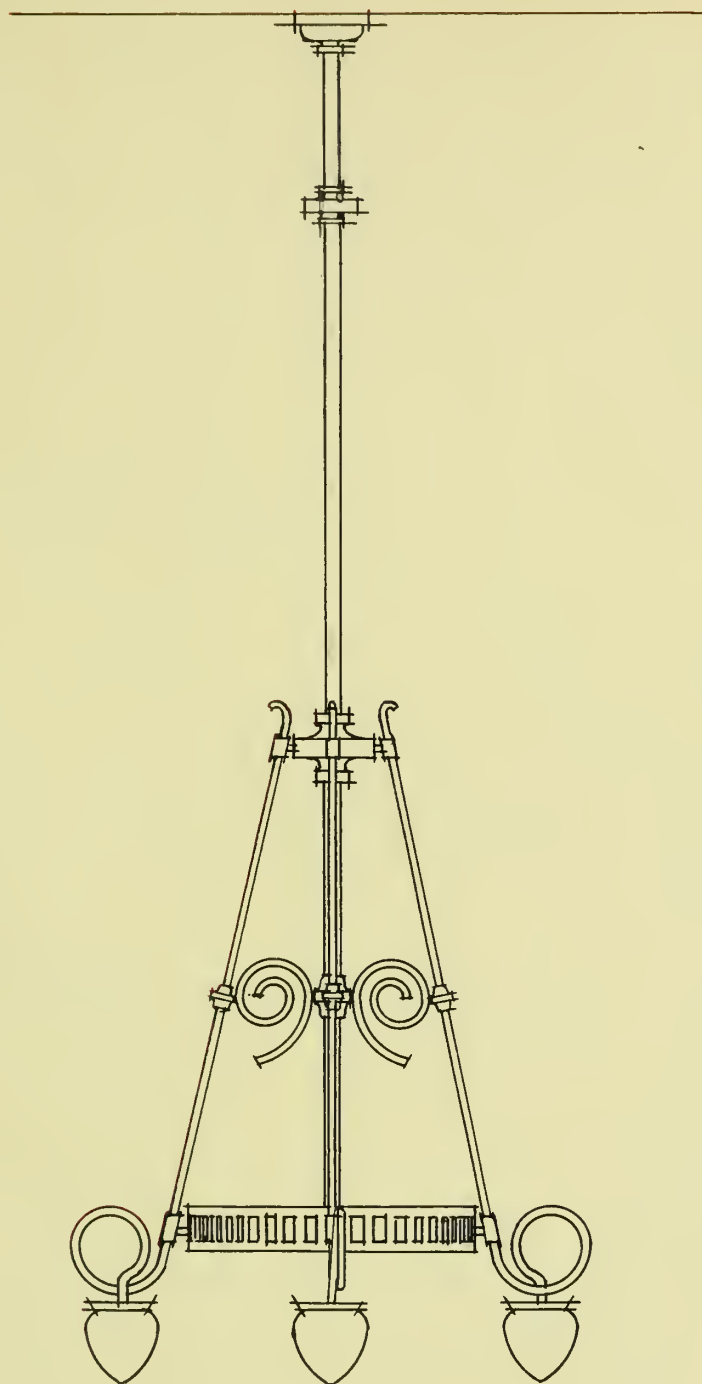illumination along corresponding points
using proposed placing of Fixtures.

Fig. 4

60 Watt - 50 C. P. Mazda

HOLOPHANE CLASS B - STALACTITE.
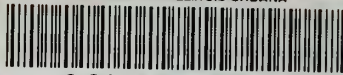
DESIGN FOR PROPOSED CHANDELIER.